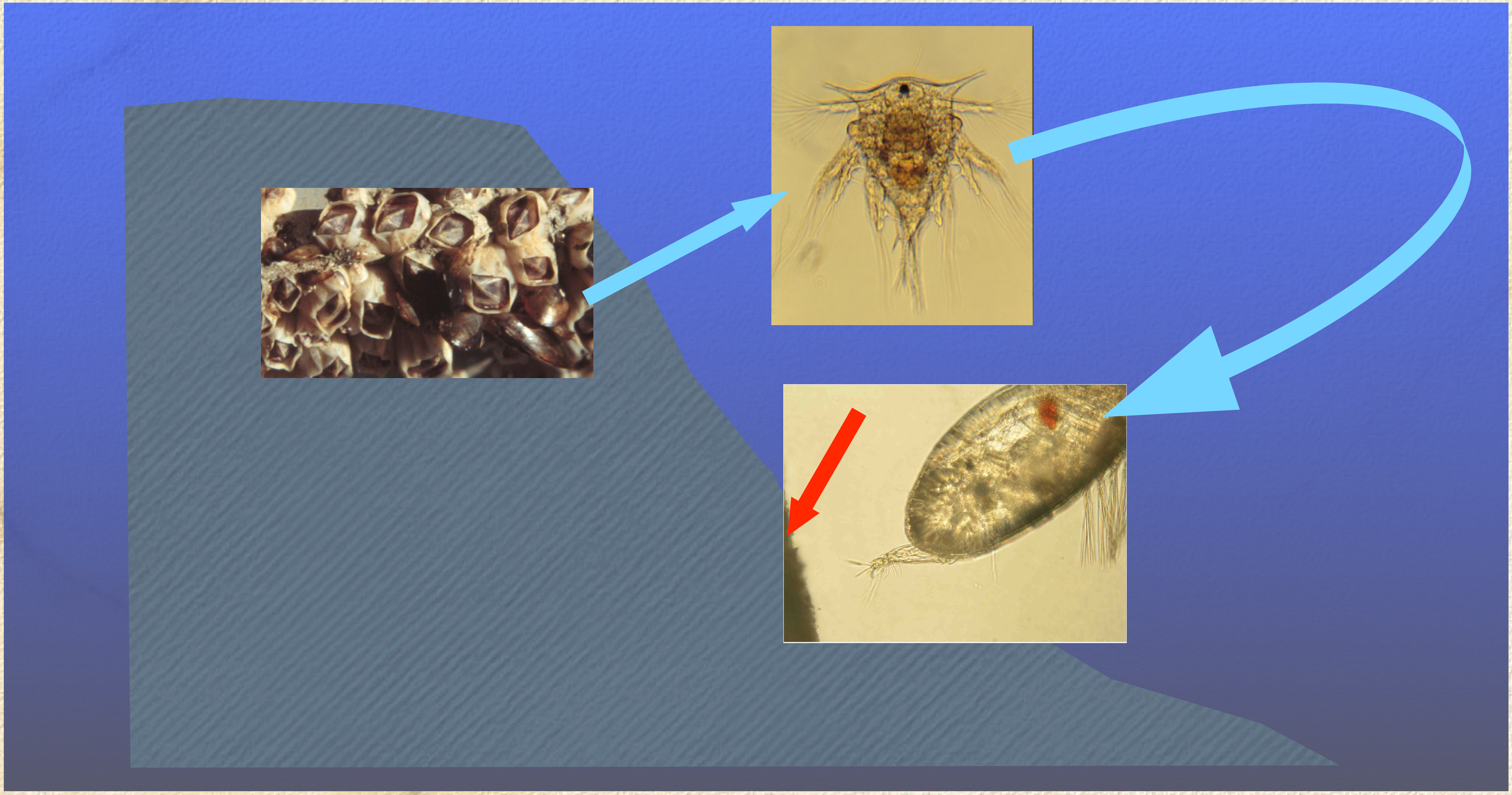
Larval settlement
- a physical perspective

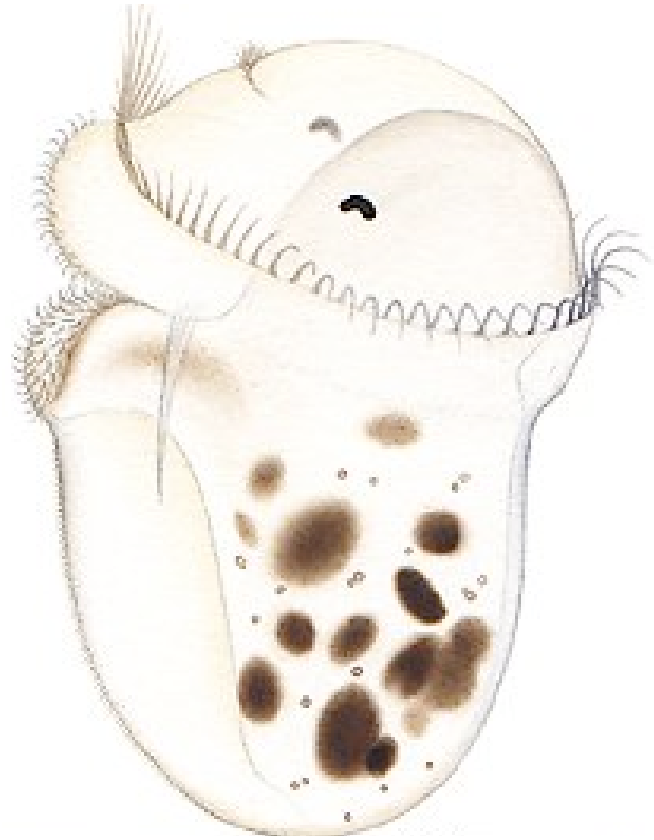
Per Jonsson
Tjärnö Marine Biological Laboratory
Göteborg University

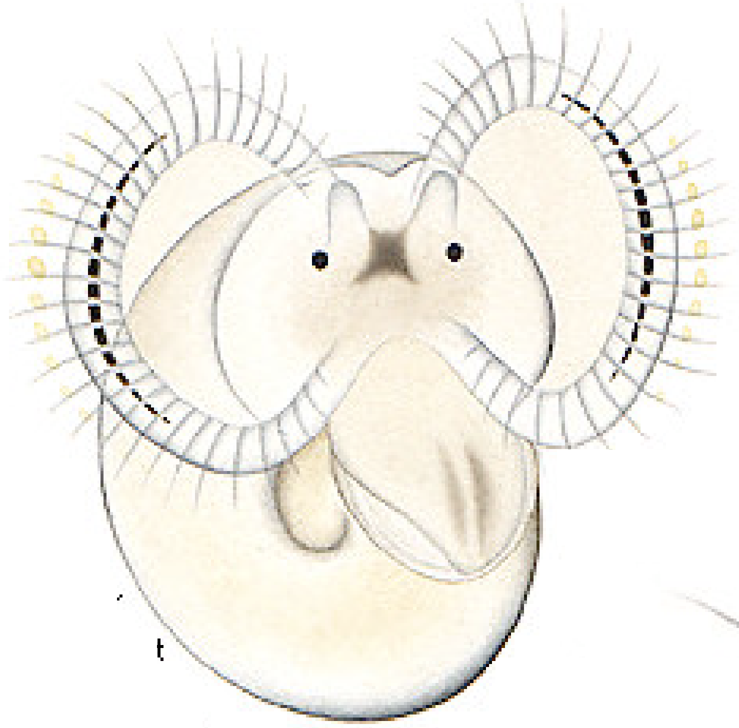
NMA course, Bergen 2005

The problem for marine larvae

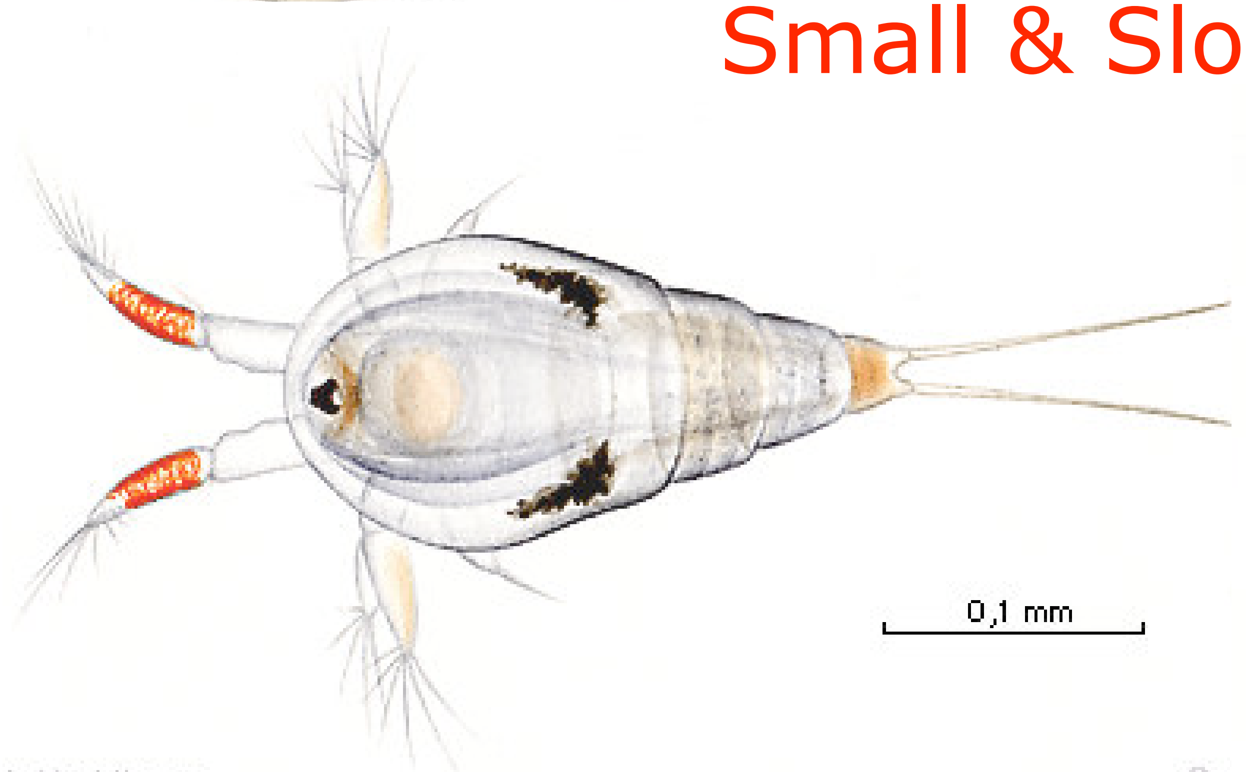


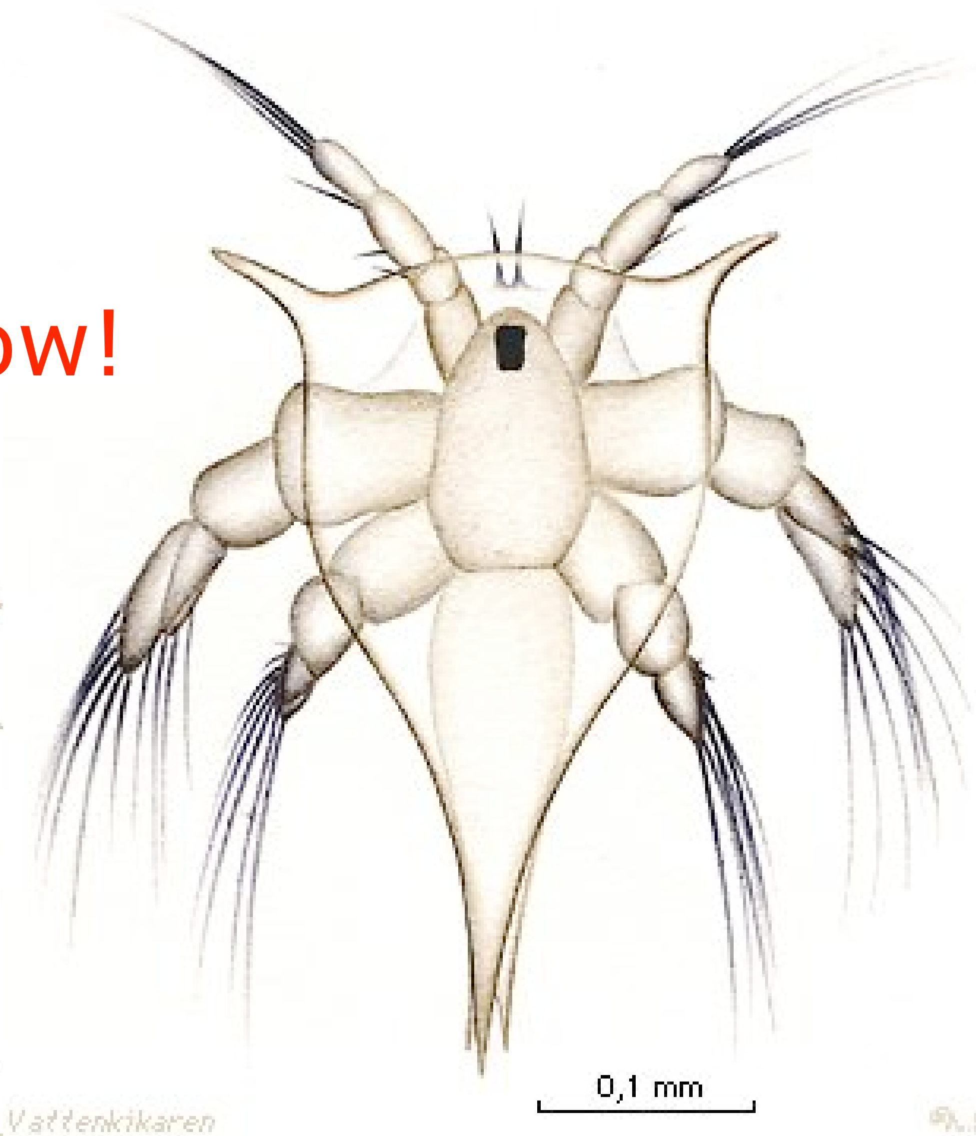
Marine larvae





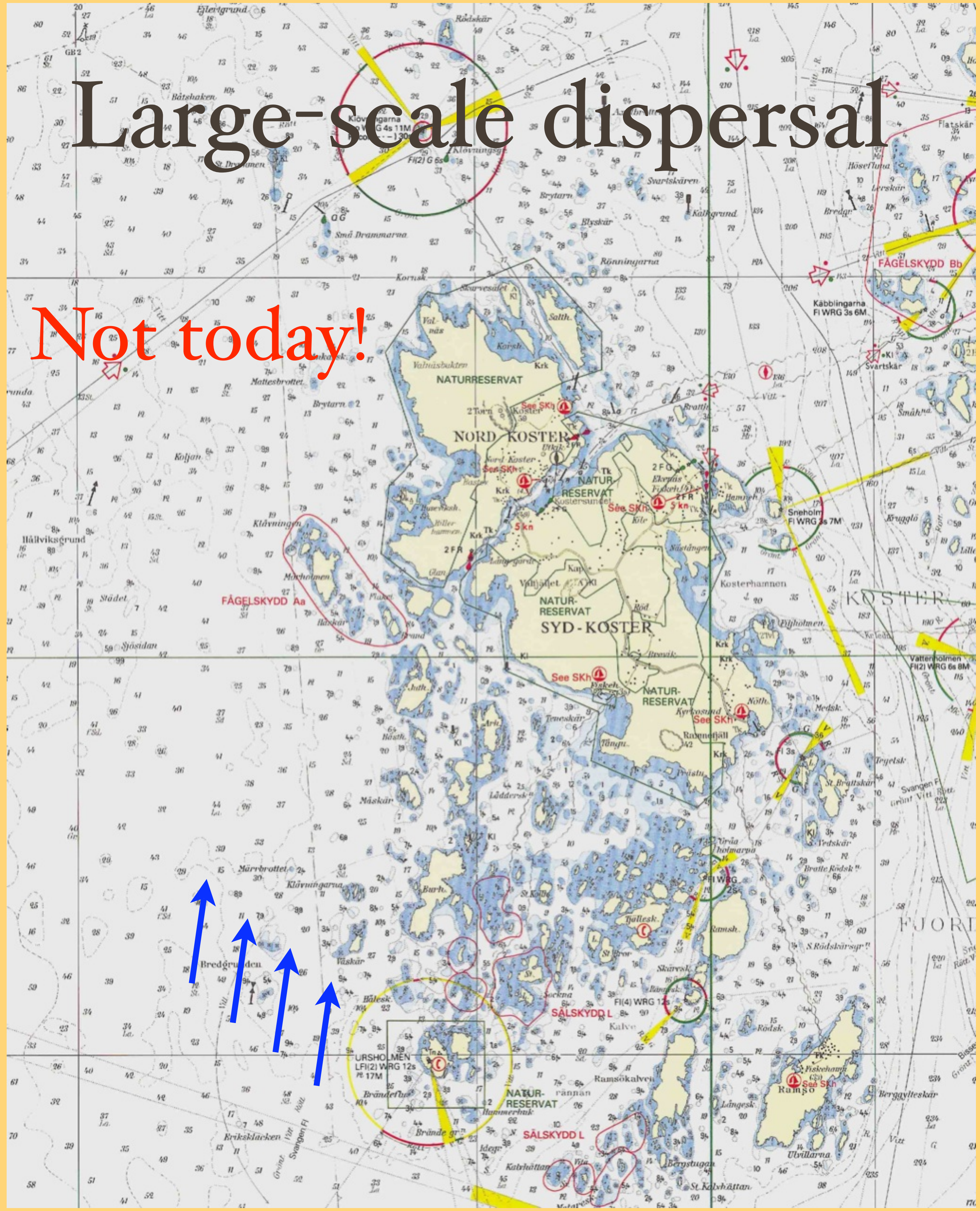
Small & Slow!



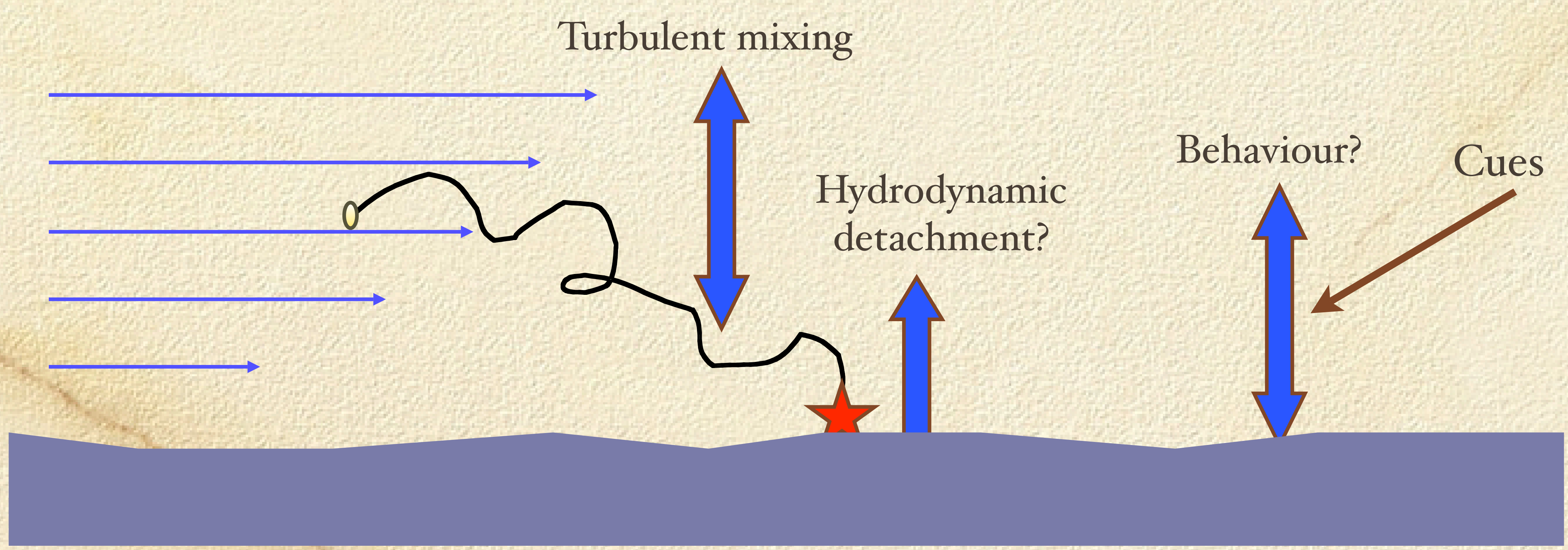


Large-scale dispersal

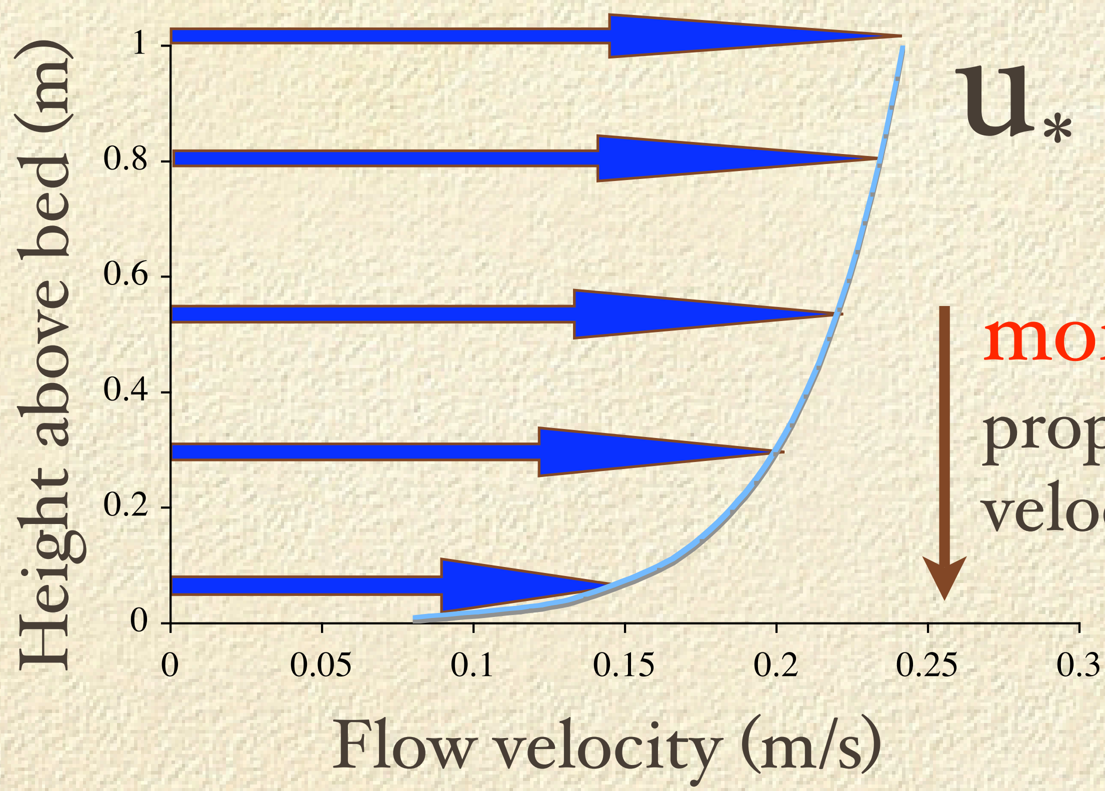
Not today!



Settling in a turbulent boundary layer



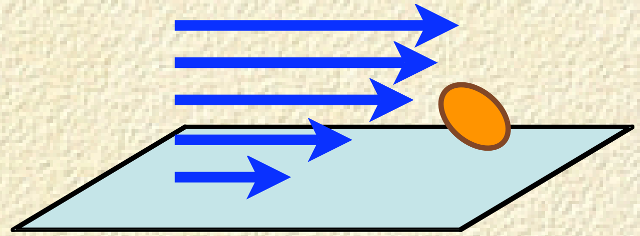
Boundary-layers

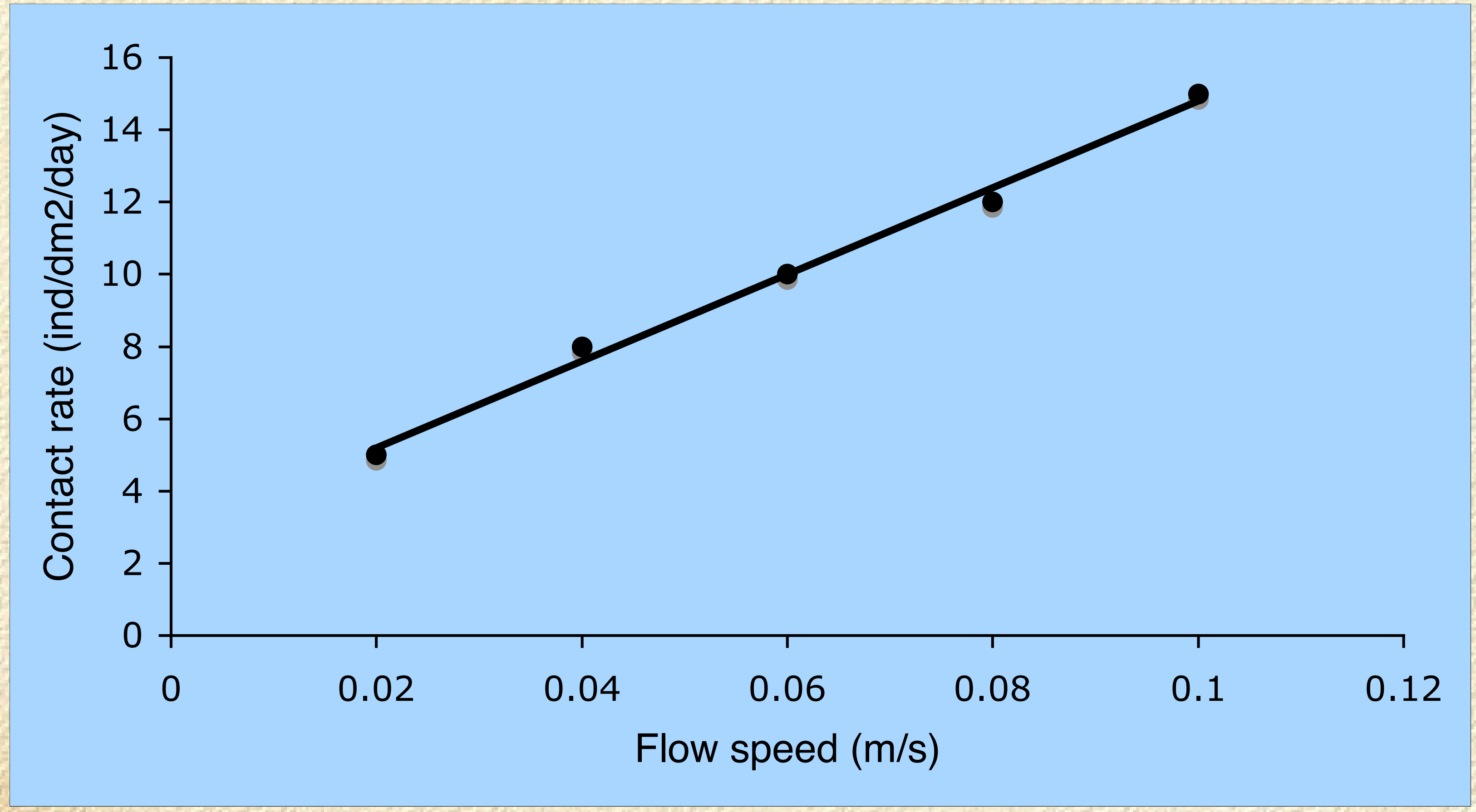


u_* friction velocity

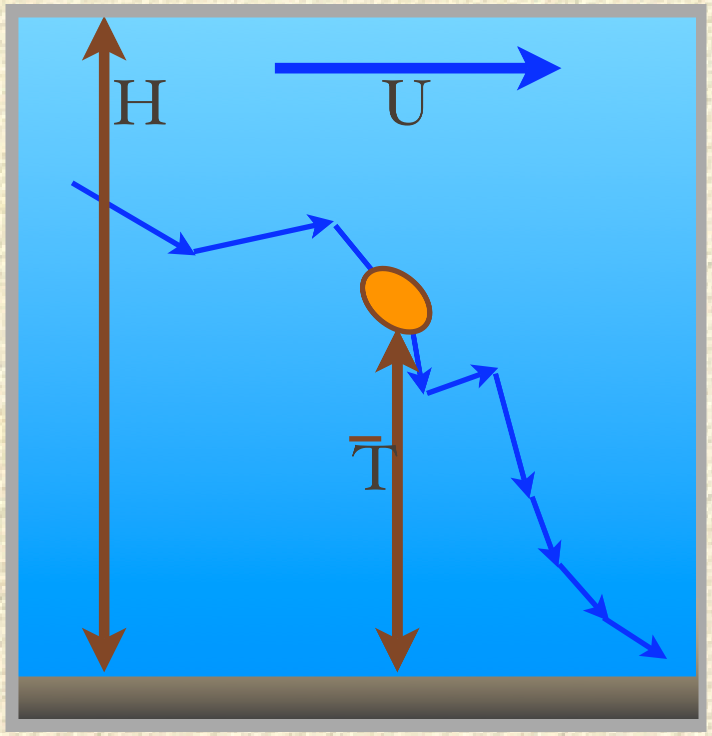
momentum flux
proportional to the velocity gradient

In the local domain, what is the contact rate?





How often will a larva hit the bottom?



$$\bar{T} \approx \frac{3H}{u_* 4\kappa}$$

Denny (1988)

H=10 m, U=0.2 m/s

T̄= 0.5 h

H=2 m, U=1 m/s

T̄= 1 min

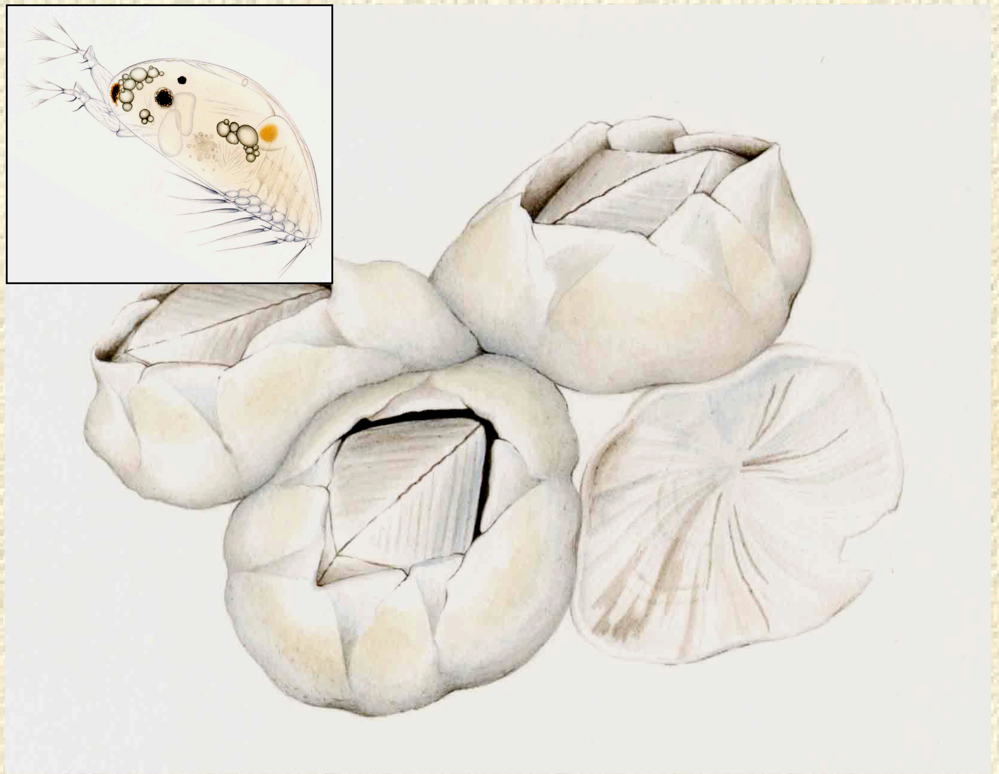
A full description: McNair et al. 1997, J theor Biol 188: 29-52

Environmental cues guide larvae to preferred sites

Barnacle cyprid larva exploring a surface

Role of larval behaviour

- Larval exploring behaviour and response to environmental cues well known
- The link between larval choice and post-settlement fitness is poorly documented



Is flow an important cue?

+ Flow brings food to sessile suspension feeders

+ Flow ensures an exchange of gases and waste products

+ Flow may increase fertilization success through enhanced encounter between gametes

- Flow imposes a mechanical stress

- Flow may decrease fertilization success through dilution of gametes

Flow effects on larval behaviour

- Larval attachment (Crisp 1955)
- Larval choice (Mullineaux & Butman 1991)
- Larval settlement (Qian 2000, Jonsson et al. 2004)

But, do these responses to flow translate to improved fitness?

Hypothesis tested

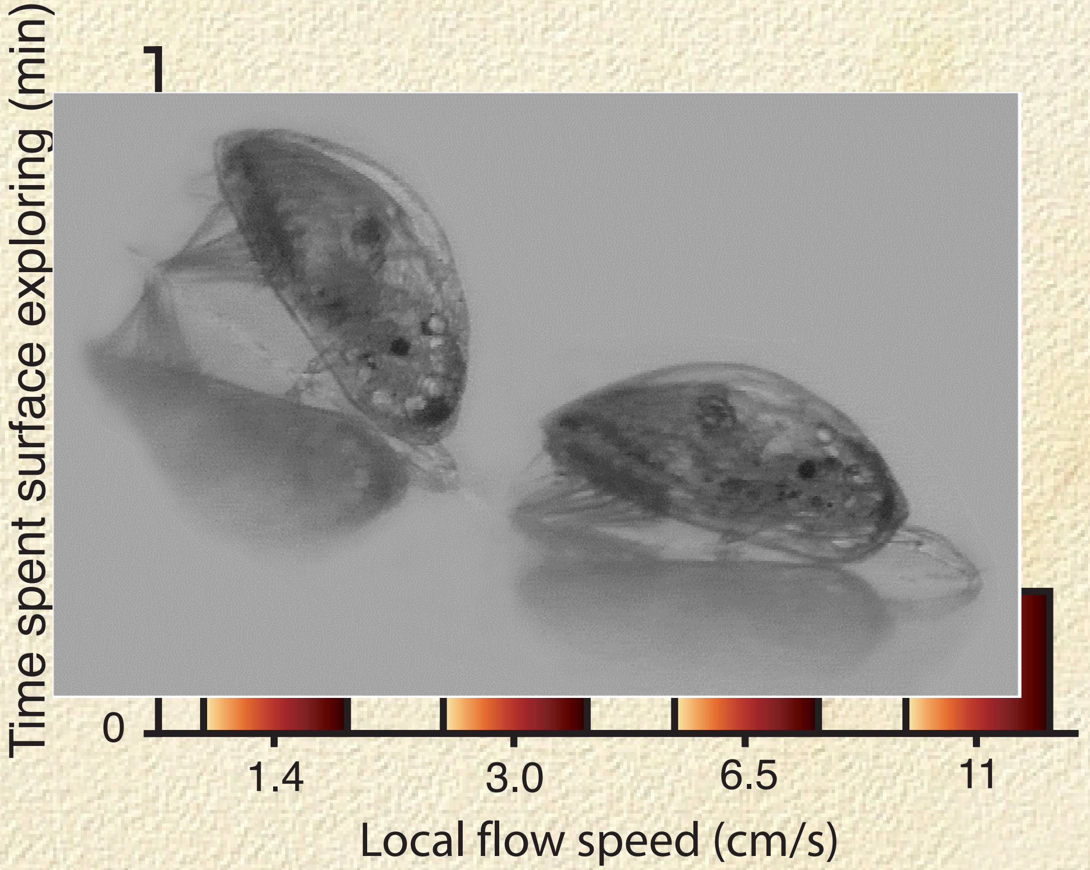
Larval selection of flow regime is adaptive

Larval flow selection is predicted to result in:

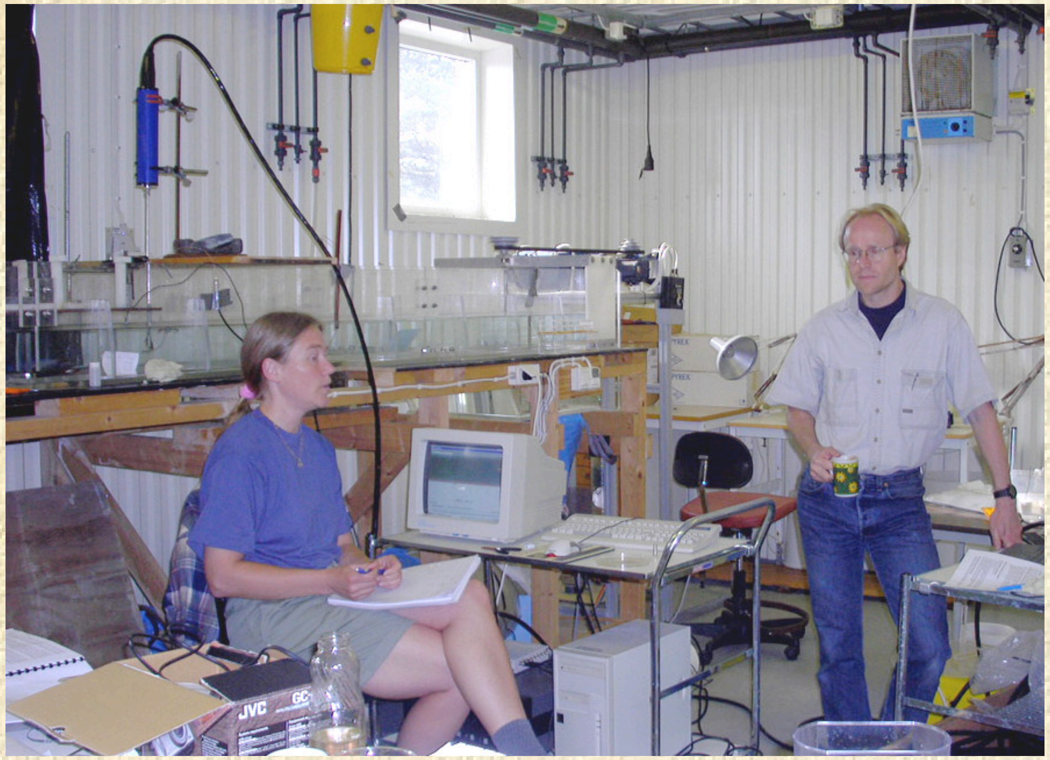
- Optimal feeding rate in post-settlement barnacles
- Increased growth in post-settlement barnacles
- Increased survival in post-settlement barnacles

Flow dependent larval behaviour

- At Ux 5-10 cm/s interest in exploring drops.
- Difficult to move at higher speeds
- Active rejection observed



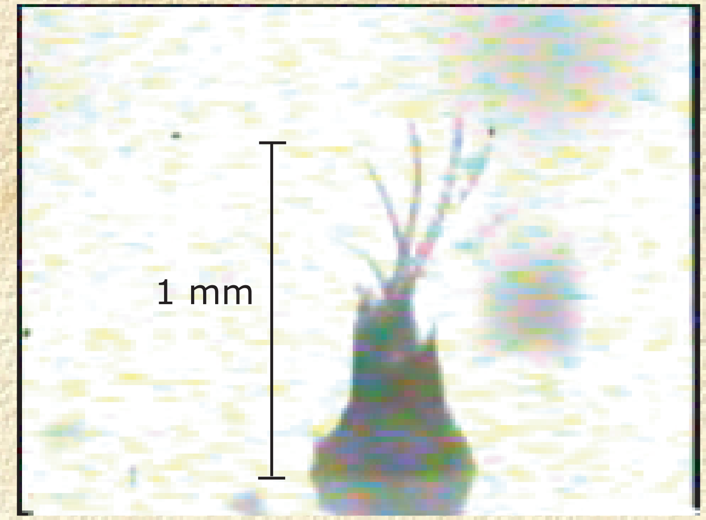
Feeding efficiency as a function of flow speed



- 3-day old barnacles (1 mm)
- U_∞ 5-50 cm/s
- Feeding behaviour
- Filter deformation
- Retention efficiency

Ux=1.4 cm/s

U∞= 5 cm/s



Ux=15 cm/s

U∞= 33 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

U∞= 49 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Direction of flow

Ux=1.4 cm/s

U∞= 5 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Ux=15 cm/s

U∞= 33 cm/s

U∞= 49 cm/s

Ux=1.4 cm/s

U∞= 5 cm/s

Ux=15 cm/s

U∞= 33 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

U∞= 49 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Ux=1.4 cm/s

U∞= 5 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Ux=15 cm/s

U∞= 33 cm/s

U∞= 49 cm/s

Ux=1.4 cm/s

U∞= 5 cm/s

Ux=15 cm/s

U∞= 33 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

U∞= 49 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Ux=1.4 cm/s

U∞= 5 cm/s

Ux=15 cm/s

U∞= 33 cm/s

Ux=2.6 cm/s

U∞= 11 cm/s

U∞= 49 cm/s

Ux=7.5 cm/s

U∞= 21 cm/s

Reduction of projected filter area

100 %

U_x=2.6 cm/s

U_∞= 11 cm/s

81 %

U_x=7.5 cm/s

U_∞= 21 cm/s

45 %

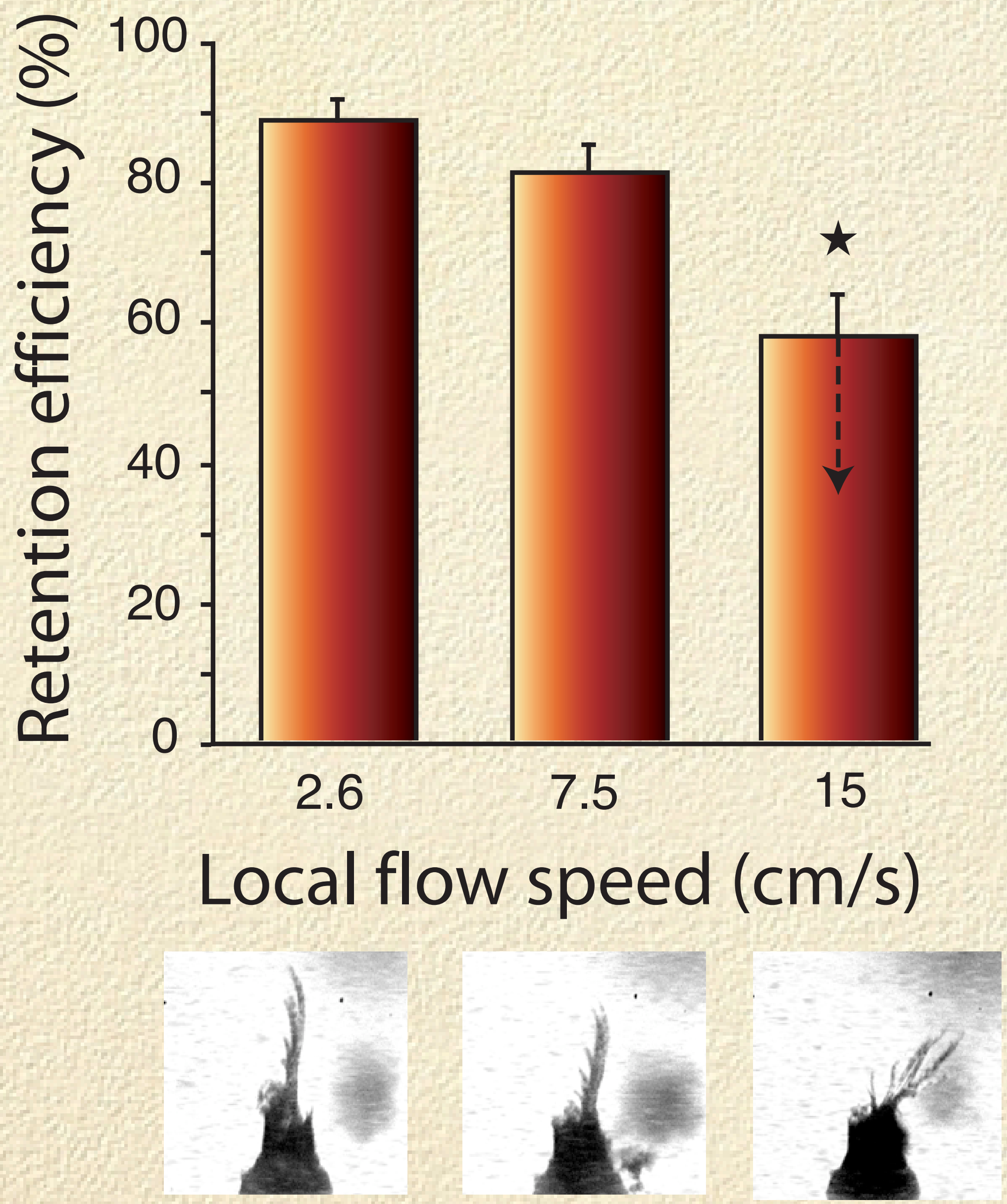
U_x=15 cm/s

U_∞= 33 cm/s

Retention efficiency

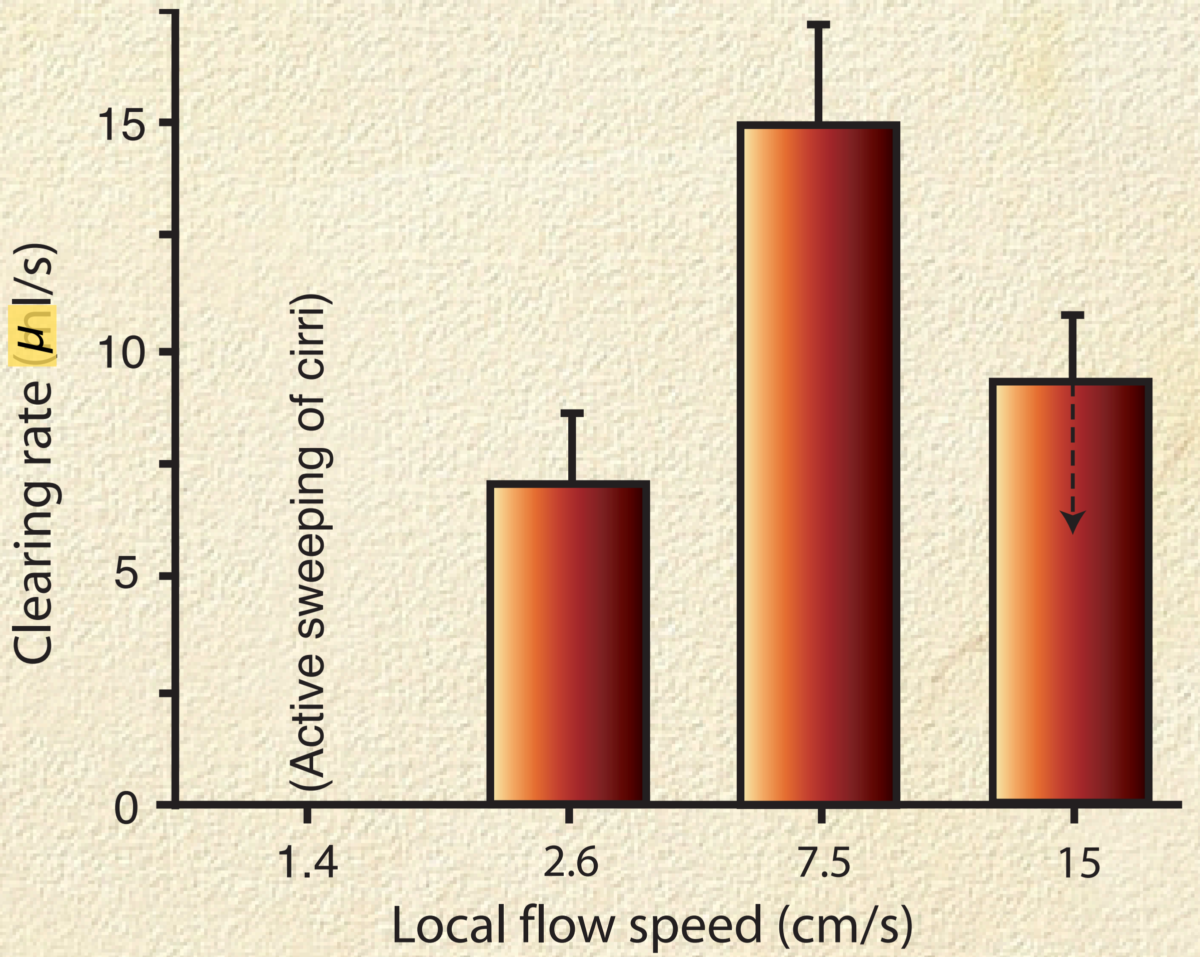
- Cellulose particles 30 -50 µm
- Video recordings (frame rate)

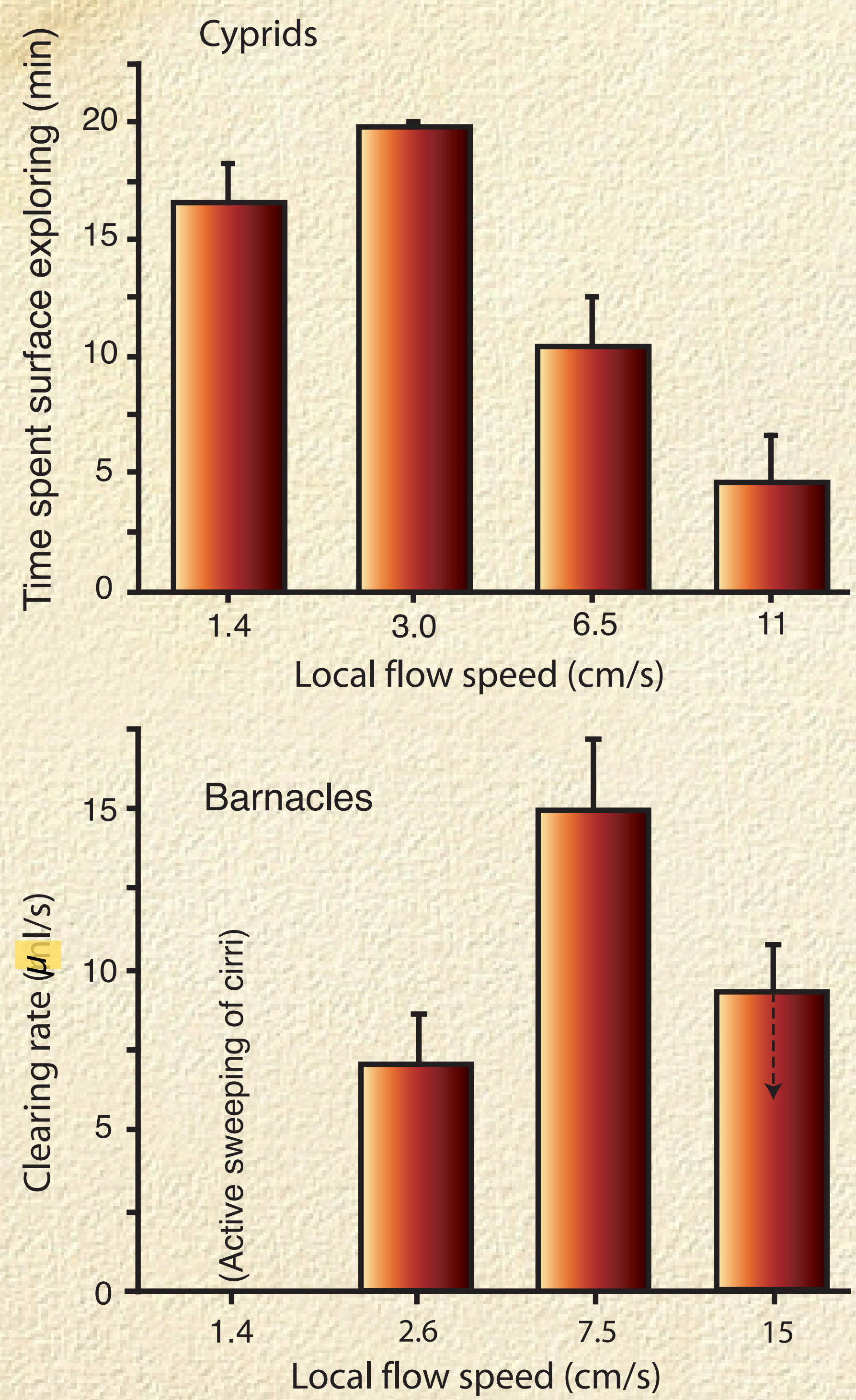
Retention efficiency



Clearing rate

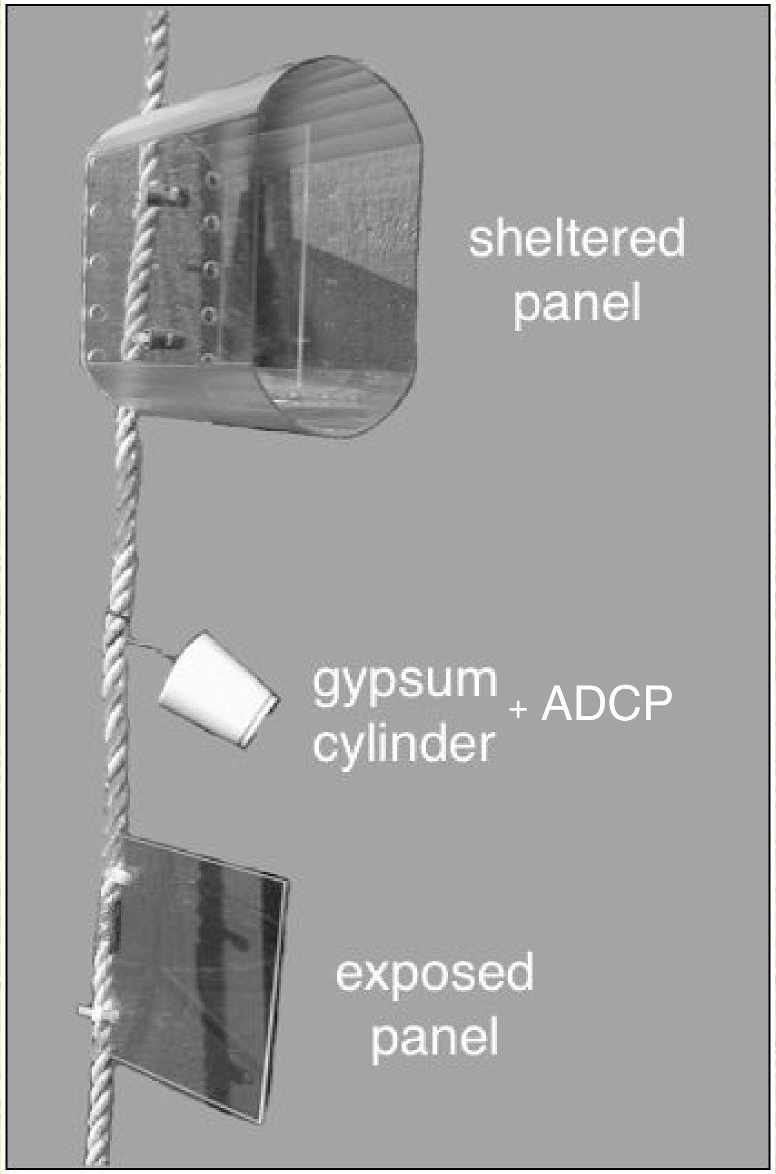
- Filter deformation
- Retention efficiency
- Time spent feeding
- Local flow velocity



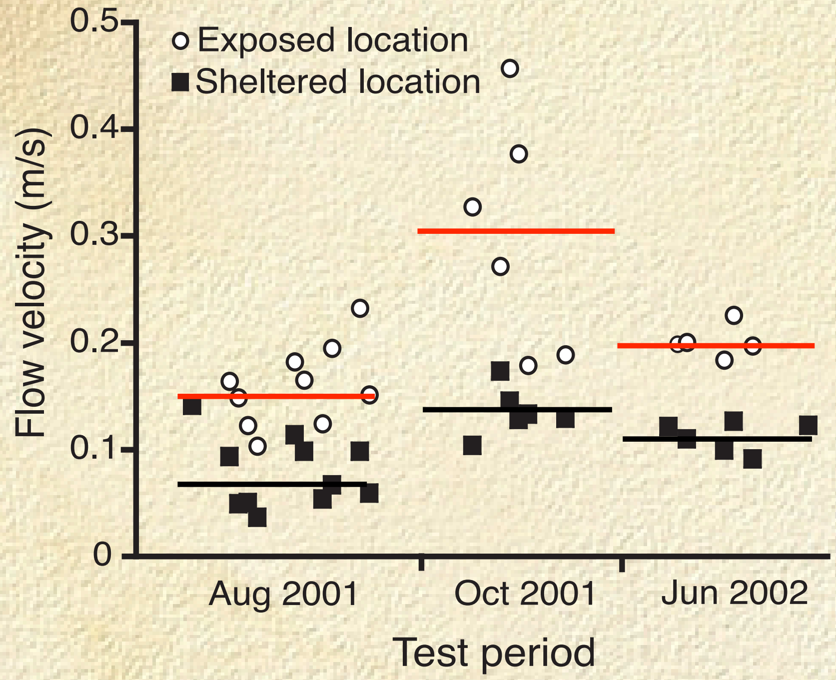

Cyprids
Time spent surface exploring (min)
0
5
10
15
20
1.4
3.0
6.5
11
Local flow speed (cm/s)
Barnacles
Clearing rate (μl/s)
(Active sweeping of cirri)
0
5
10
15
1.4
2.6
7.5
15
Local flow speed (cm/s)

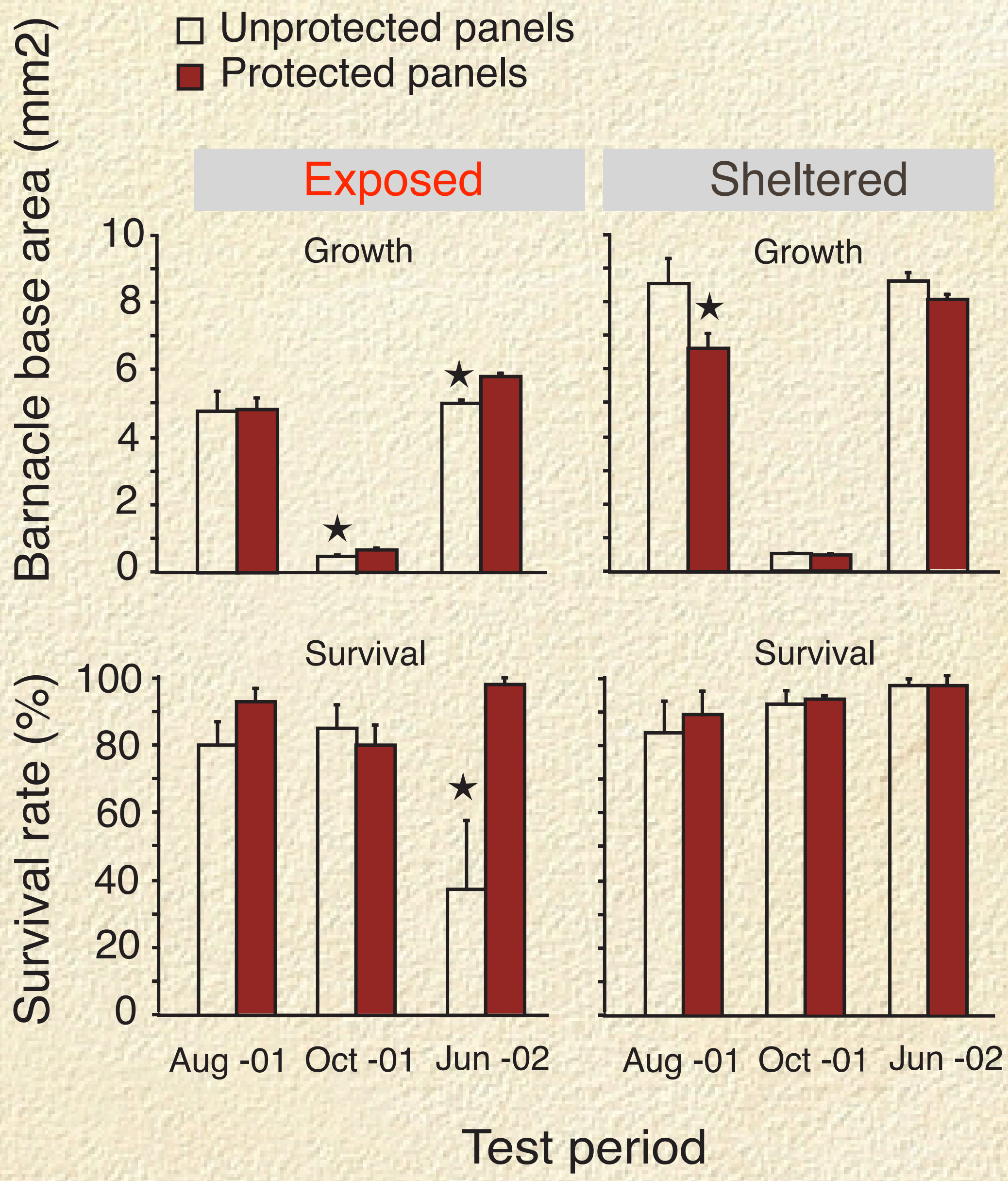
Growth and survival as a function of field flow

- Newly metamorphosed barnacles
- Sheltered and exposed location
- Manipulated flow
- Measured ambient flow speed
- 2 weeks exposure



Growth and survival





Conclusions

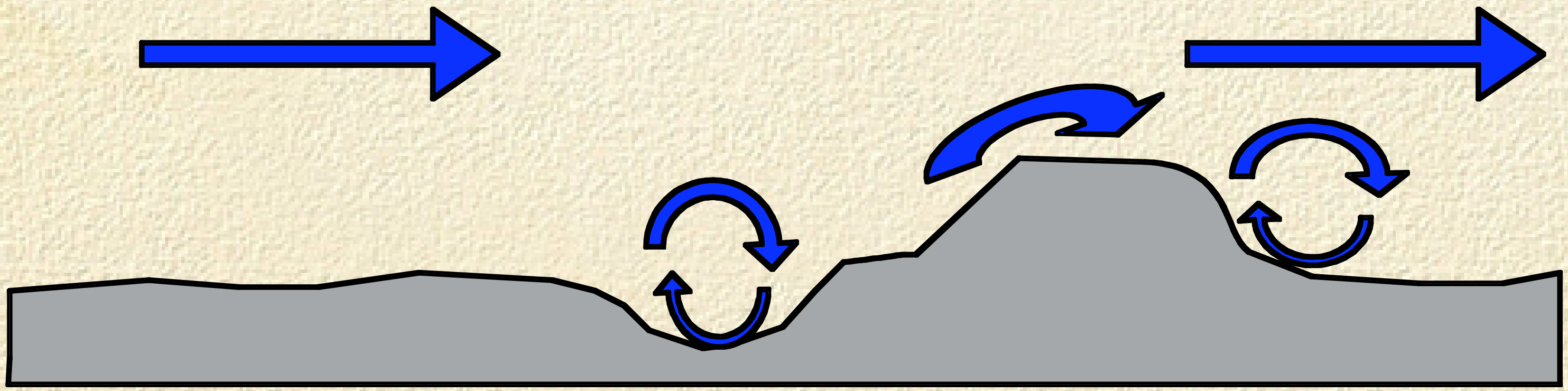
- Larval preference for flow regime can be linked to post-settlement growth and survival
- In flow velocities above 10-15 cm/s growth and survival of juvenile *Balanus improvisus* barnacles is restricted
- Flow effects on larval behaviour and juvenile fitness affect the spatial distribution of this barnacle

Speculations

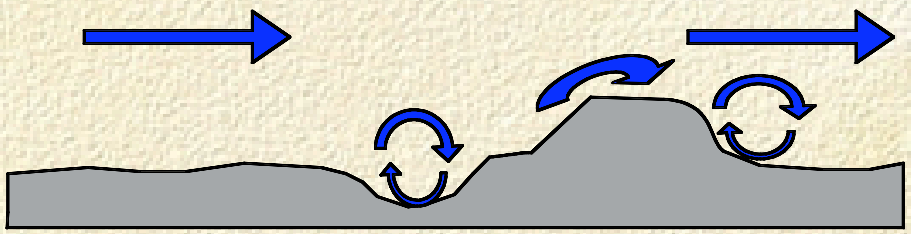
- Larval choice may be adaptively connected to the very sensitive time after metamorphosis. Mechanical strength scales to the 4th power of feeding appendage size while drag only scales with the 2nd power.

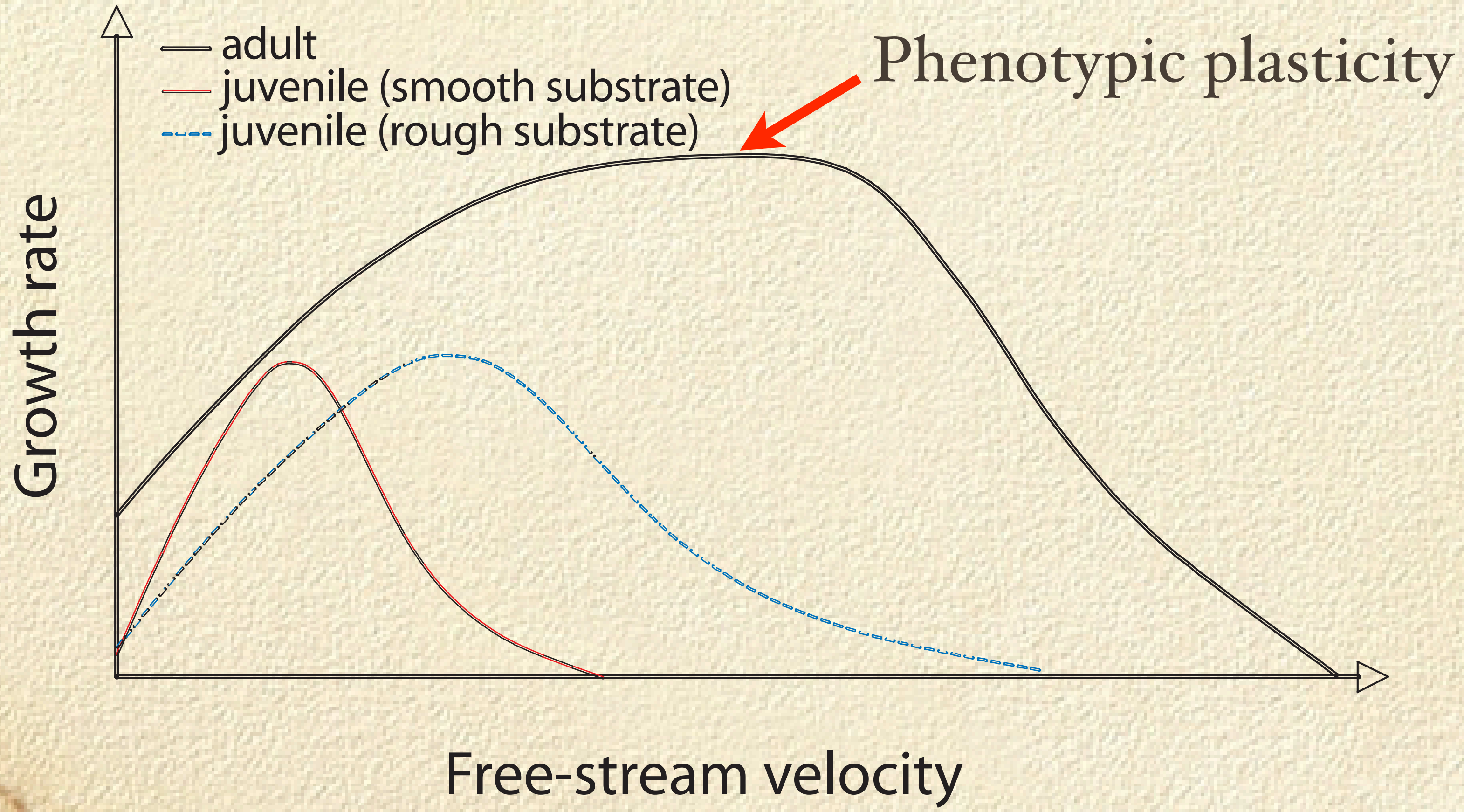
- Is the well-known cyprid preference for small pits and depressions actually a response to find sites with reduced local flow speed?

Small-scale flow variations

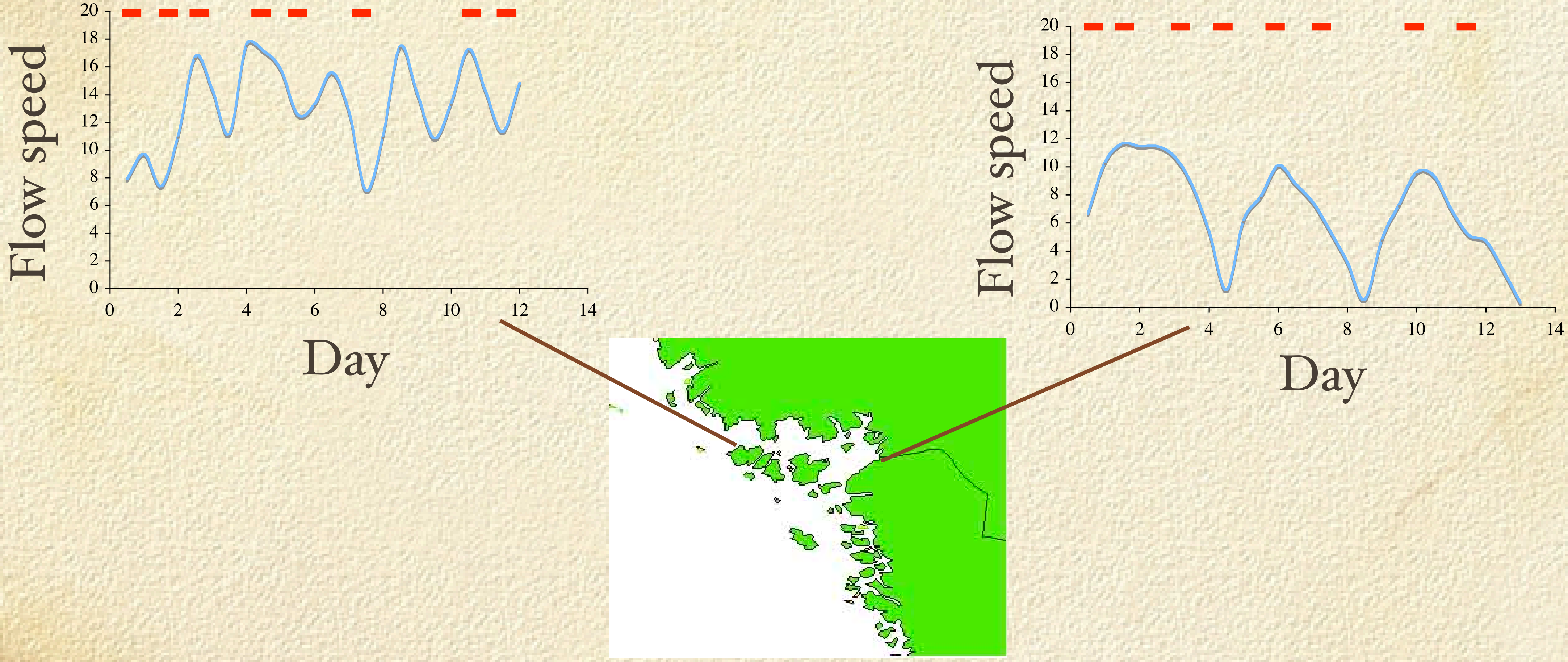


Conceptual model



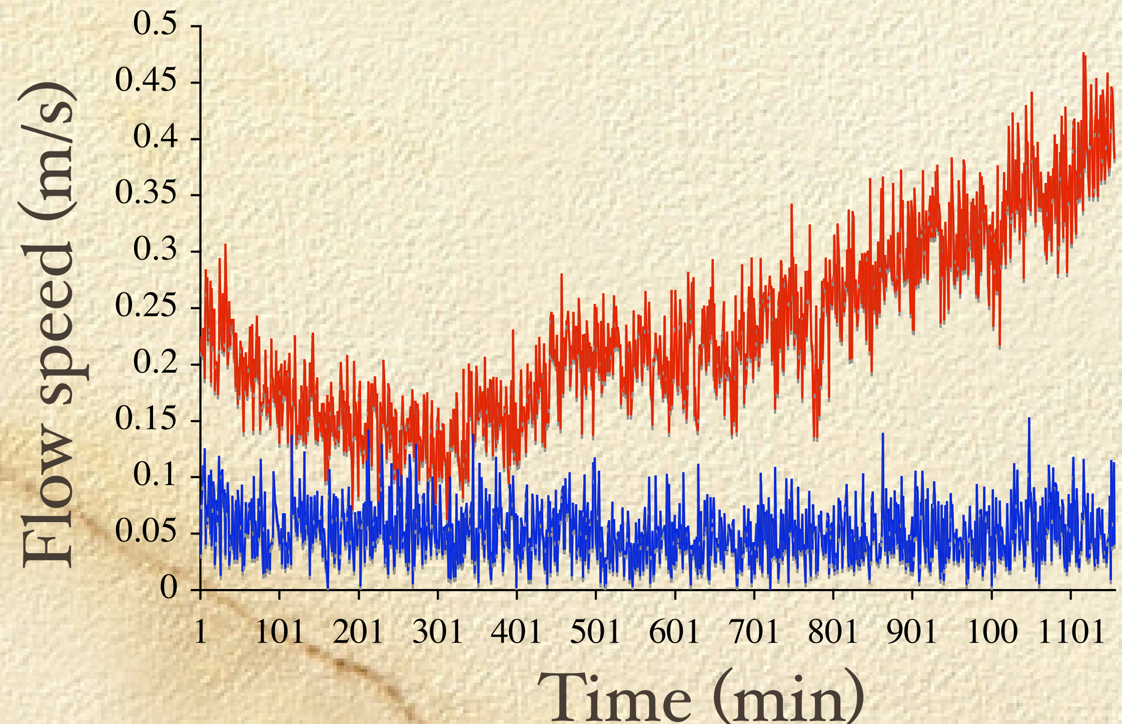


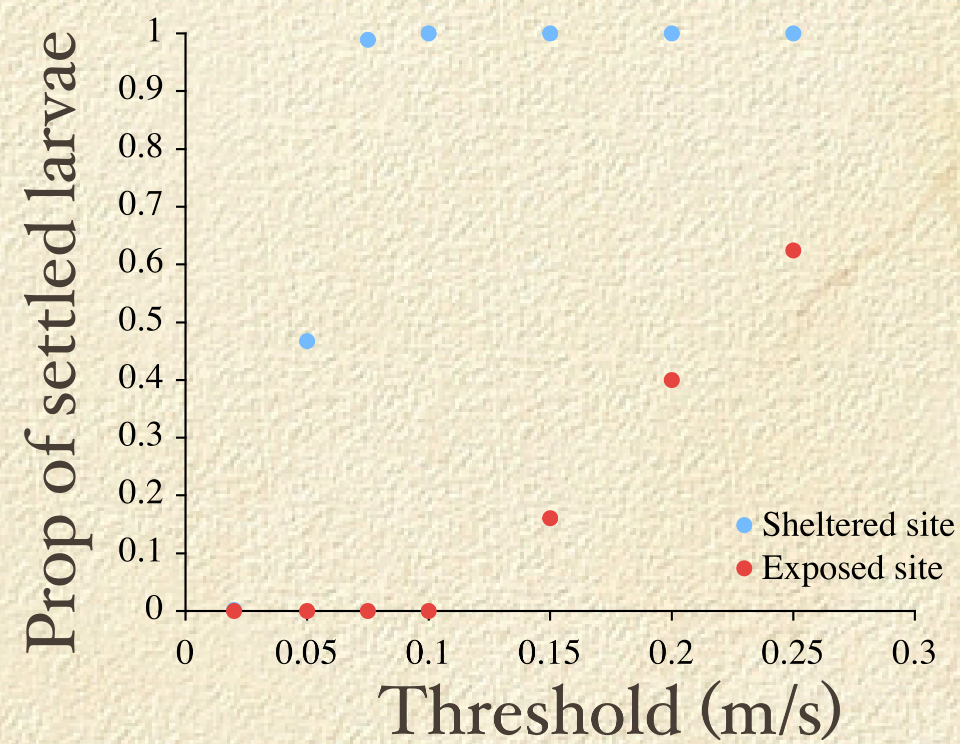
Can larval preference for flow speed determine large-scale patterns?



Yes, probably.....

- A model examines ADCP current data
- Random samples of flow velocity of 15 min are compared to critical thresholds:
  - mean flow speed during a short interval
  - max flow speed during a short interval





In collaboration with:

- Ann Larsson, Göteborg University
- Lena Granhag, Göteborg University


Thank you!